An Extended Definition Television System Using Quadrature Modulation of the Video Carrier with Inverse Nyquist Filter

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Abstract **--- A QUadrature Modulating Extended definition television system -QUME- , which enhances NTSC to higher definition , is proposed. The QUME system uses quadrature modulation of video carrier with inverse nyquist filter and creates an independent transmission channel (Bandwidth : 1MHz) without using additional channel resources. One of the features of QUME is that the multiplexed signal hardly interferes with the conventional TV receivers, and another is that there is no crosstalk between the multiplexed signal and the main NTSC signal. These features enable a wide aspect ratio image to be transmitted as well as high frequency components of luminance and/or chrominance signals, while keeping compatibility with the NTSC system.**

I. INTRODUCTION

Recently, improvement on television receiver has been remarkably progressed such as large screen CRT, utilizing digital processing and IDTV. Still now, strong demand for higher quality picture exists. Since the 1970's, much efforts for developing a high definition television system have been made by engineers led by Fujio [1] in NHK (Japan Broadcasting Corporation). This HDTV system primarily aims at DBS (Direct Broadcasting Satellite) in Japan, and has no compatibility with the present NTSC system.

On the other hand, some proposals of NTSC compatible high definition television system have been made such as SLSC [2] and FUCE [3] system. The SLSC system uses 2 channels to transmit higher bandwidth of luminance and chrominance signals and LoCicero [4][5] extended this system to transmit wide aspect ratio image. Fukinuki [3] uses only 1 channel to transmit over 6MHz luminance signal, keeping receiver and transmission compatibility with NTSC. His system uses vacant frequency bands in the first and third quadrants which conjugate with the carrier chrominance signal, and transmits high frequency components of luminance or chrominance signal of a still picture. The FUCE system cannot transmit high frequency components of motion parts of images, and therefore cannot be used to transmit wide aspect ratio image.

The authors have developed a new extended definition television system using quadrature modulation of video carrier with inverse nyquist filter -QUME- [6]. The QUME system uses a single channel (Bandwidth : 6MHz) and keeps full compatibility with NTSC. These are very important matters especially in Japan, because there are no more channel resources available and 70 million NTSC receivers in use. [7] The first feature of QUME is that the multiplexed signal hardly interferes with the main NTSC signal, especially if detected using a PLL synchronous detector. The second feature is there are no crosstalk between the multiplexed signal and the main signal, and therefore edge portions of wide aspect ratio image as well as high frequency components of luminance and/or chrominance signal in the motion part of the image can be transmitted.

Considering that the nyquist filter and PLL synchronous video detector are universally used in most of the conventional TV receivers, an inverse nyquist filter is adopted for filtering the multiplex signal before added to the main NTSC signal. By using this filter, the multiplexed signal never interferes with the main NTSC signal in principle if detected by the PLL synchronous detector, because the multiplexed signal is shaped into double side band signal at the receiver.

Detailed principles of the QUME system is described in the next section. Experimental results of transmitting high frequency component of luminance signal and simulation results of transmitting wide aspect ratio image are discussed in section III and IV, respectively.

II. QUADRATURE MODULATION

A. Modulation of Multiplex Signal

The conventional NTSC signal has the frequency spectrum as shown in Fig.1 (a), which is called VSB-AM (Vestigial Side Band Amplitude Modulation). In this figure, P_1, C and S indicate video carrier, chrominance subcarrier, and sound subcarrier, respectively, and the lower part of bandwidth than P_1 is 1.25MHz. Considering a multiplex signal which bandwidth is 1.25MHz, a second video carrier P_2 is used, which phase is 90 degree different from P_1 as shown in Fig.1 (b). Next step is band limiting of this modulated signal as shown in Fig.1 (c). This band limiting is -6dB at video carrier P_2, 0dB at P_2 -1.25MHz, and - infinite at P_2+1.25MHz. This characteristic is symmetrical to the nyquist filter at the video IF stage in the conventional TV receiver. This band limiting characteristic is called an *Inverse Nyquist Filter*. As the last step, combining the main signal of Fig. 1 (a) and the multiplex signal of Fig. 1 (c), the QUME signal is obtained as shown in Fig.1 (d). Quadrature modulation of video carrier with the inverse nyquist filter is a feature of the QUME system. Using the multiplex signal, edge portions of wide aspect ratio image as well as frequency-shifted high frequency components of luminance and/or chrominance signal can be transmitted.

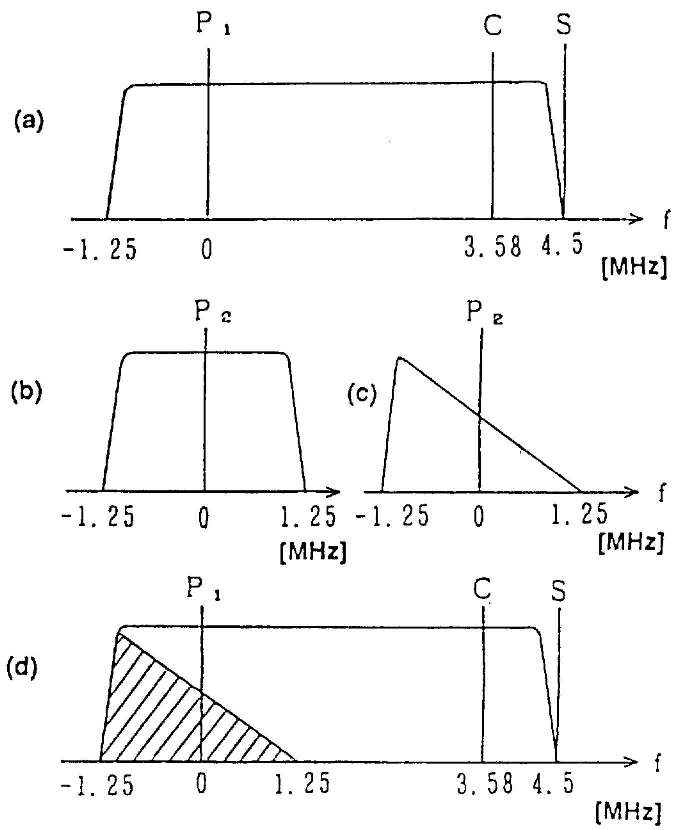


Fig. 1. Frequency Spectrum of QUME
(a) NTSC (b) Multiplex Signal (c) Multiplex Signal after Inverse Nyquist Filter (d) QUME

B. Demodulation in a conventional NTSC receiver

Now let us consider receiving of the QUME signal as described before by the conventional receiver. This signal contains the multiplexed signal which is filtered by the inverse nyquist filter at the transmitter. In the conventional receiver, incoming signal is band limited by a nyquist filter at the video IF stage and shaped into the spectrum shown in Fig.2 (a). The vector chart of this processing is shown in Fig.2 (b). In this figure, I_1 is the video carrier of the main signal and I_2 indicates the carrier of the multiplexed signal, which is 90 degree different from I_1 and suppressed at the transmitter. In Fig.2 (b), a_u is the upper side band signal and a_L is the lower side band signal; the length of both vectors are different from each other because the main NTSC signal is vestigial side band. The a_u and a_L signals are decomposed to orthogonal components a_1 and a_2. As the multiplexed signal is double side band, the upper and lower side band signals, $\mathbf{b_u}$ and $\mathbf{b_L}$, have the same length and the composed vector of them, $\mathbf{b_2}$, is in the direction of I_2. If

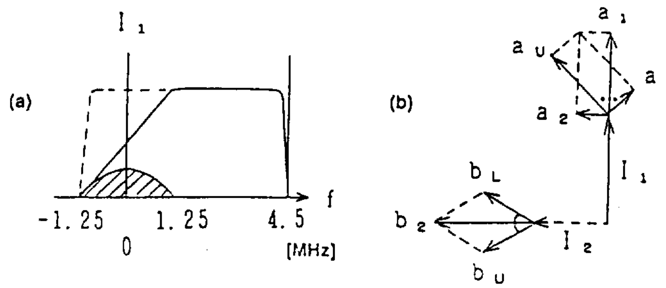


Fig. 2. Demodulation in a conventional receiver
(a) Spectrum (b) Vector Chart

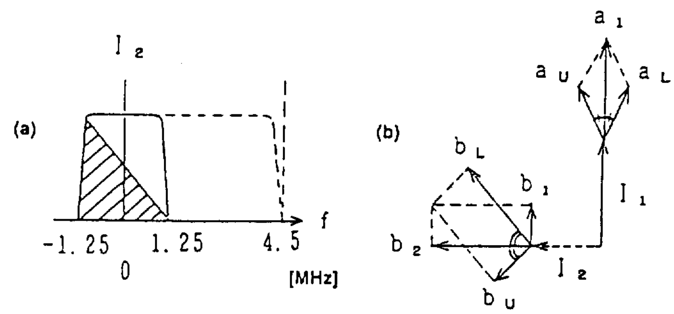


Fig. 3. Demodulation in a QUME receiver
(a) Spectrum (b) Vector Chart

the multiplexed signal is detected along $\mathbf{I_1}$ by the synchronous detector, there arises no quadrature distortion caused by vector $\mathbf{a_2}$ and $\mathbf{b_2}$. Thus the multiplexed signal $\mathbf{b_2}$ never interferes with the NTSC signal in the receiver with the synchronous video detector.

On the other hand, the multiplexed signal $\mathbf{b_2}$ is detected also by the envelope video detector, but power of crosstalk by the multiplexed signal is 10dB less than the case without the inverse nyquist filter.

C. Demodulation in a QUME receiver

In a QUME receiver, the multiplexed signal is detected by the synchronous detector after passing through a band-pass filter from the tuner. This band-pass filter eliminates signals greater than 1.25MHz of the main NTSC signal and shapes it to double side band as shown in Fig.3 (a). The vector chart of this signal is shown in Fig.3 (b). In this figure, $\mathbf{b_u}$ and $\mathbf{b_L}$ are upper and lower side band components of the multiplexed signal, and are decomposed to orthogonal vectors $\mathbf{b_1}$ and $\mathbf{b_2}$, which length are different because the multiplexed signal is vestigial side band. On the other hand, $\mathbf{a_u}$ and $\mathbf{a_L}$ are upper and lower side band components of the band limited main signal, and composed to vector $\mathbf{a_1}$, which is in the direction of $\mathbf{I_1}$ because this signal is double side band. Thus the multiplexed signal is detected along $\mathbf{I_2}$ by the synchronous detector without quadrature distortions of vectors $\mathbf{a_1}$ and $\mathbf{b_1}$.

D. QUME Transmitter and Receiver

Fig.4 shows the complete QUME system of transmitter and receiver. In addition to the conventional broadcasting system, quadrature modulator and demodulator, and inverse nyquist filter are newly added. Considering the cost performance of the total system, cost increase of the receiver should be minimum. Since the QUME receiver needs no field or frame memories, and the PLL synchronous detector is already equipped in most of the conventional receivers, a QUME receiver can be realized by slightly modifying a conventional receiver with little cost increase.

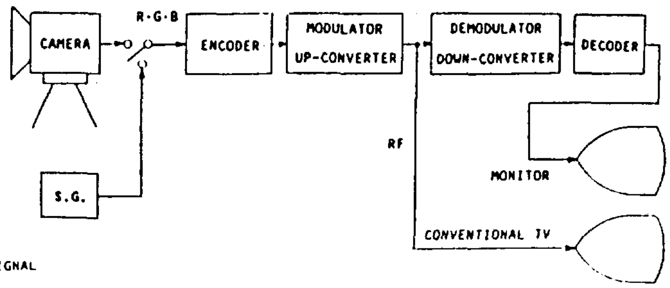


Fig. 5. Experimental QUME system

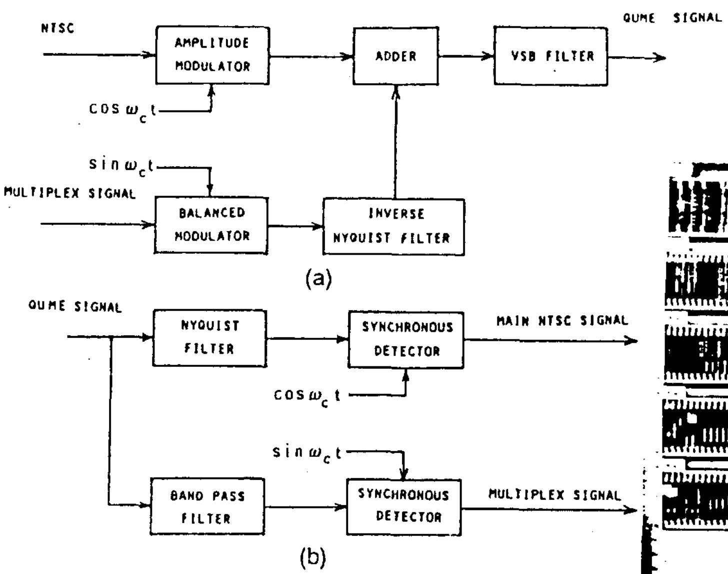


Fig. 4. Block Diagram of the QUME system
(a) Transmitter (b) Receiver

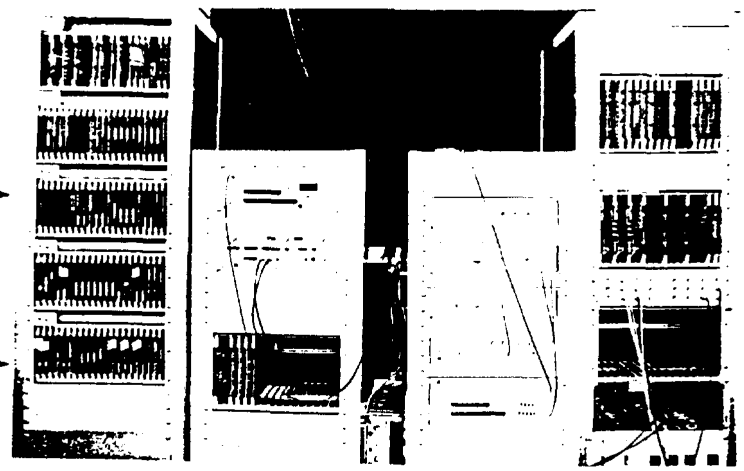


Fig. 6. Photograph of the Experimental System

III. EXPERIMENTAL SYSTEM FOR TRANSMITTING HIGH FREQUENCY COMPONENT OF LUMINANCE SIGNAL

Using an additional channel of quadrature modulation, it is possible to transmit various multiplex signals, such as high frequency component of luminance and/or chrominance signals, edge portions of wide aspect ratio image, and sub images and sounds. As the first experimental system of QUME, high frequency component (4.2 - 5.2MHz) of luminance signal is chosen to be transmitted for system simplicity.

A. System Configuration

The block diagram of the experimental QUME system for transmitting high frequency component of the luminance signal is shown in fig.5. In this figure, the encoder receives RGB signals from a progressive scanning camera or signal generator, and encodes them to NTSC signal and composes a multiplex signal from the high frequency component (4.2 - 5.2MHz) of the luminance signal. A modulator includes a quadrature modulator and an inverse nyquist filter, and generates a QUME signal. A conventional TV receiver receives this QUME signal and displays a picture for the compatibility evaluation. On the other hand, the QUME signal is fed to down-converter that converts RF signal to IF band. The demodulator includes a PLL synchronous circuit and can demodulate both the NTSC main signal and the multiplexed high frequency component of luminance signal. The decoder includes an adder of the NTSC and multiplex signals, a motion adaptive luminance and chrominance separator, and a motion adaptive scanning converter. A progressive scanning monitor exhibits improvements of the QUME system.

Fig.6 shows a photograph of the experimental QUME system.

B. Encoder and Modulator

A detail of the encoder is shown in Fig.7. All circuits of the encoder use digital processing for system flexibility; filter characteristics and subcarrier frequency are easily changed by ROM contents.

Fundamentally, large part of the encoder is identical to the NTSC encoder, but the frequency shifter for the high frequency components of the luminance signal is new. In order to transmit high frequency component of luminance signal, Y_H, by quadrature modulation of video carrier, Y_H must be extracted from broad band luminance signal by a BPF, and converted to Y_H', the frequency shifted high frequency component. Using subcarrier f_s (=4.0MHz) in the frequency shifter, Y_H (4.2 - 5.2 MHz) is shifted to Y_H' (0.2 - 1.2MHz), that can be used as a multiplex signal of QUME. Each spectrum of this processing is shown in Fig.8. Blanking signal for modulator, in addition to NTSC and multiplex signals, is generated at this encoder.

Fig.9 shows a block diagram of the modulator and up-converter. The main NTSC signal from the encoder is amplitude-modulated by a commercially available standard modulator into IF band, and the multiplex signal is amplitude-modulated by a video carrier which phase is 90 degree shifted from that of the main carrier. The modulated multiplex signal is band-limited by the inverse nyquist filter, and added to the modulated NTSC signal after passing a switching circuit operated by the blanking signal. The multiplex signal is amplitude modulated with carrier suppression; no signal is multiplexed during horizontal and vertical blanking periods. A RF band QUME signal is obtained through the up-converter.

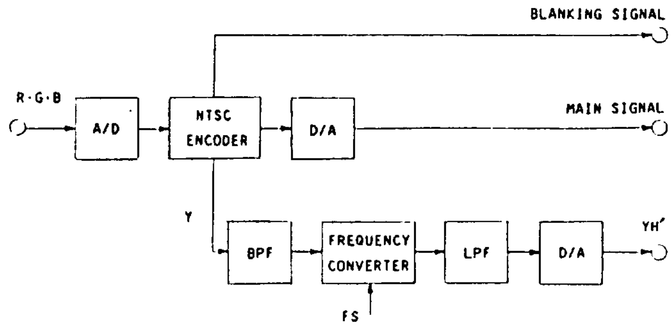


Fig. 7. Block Diagram of the Encoder

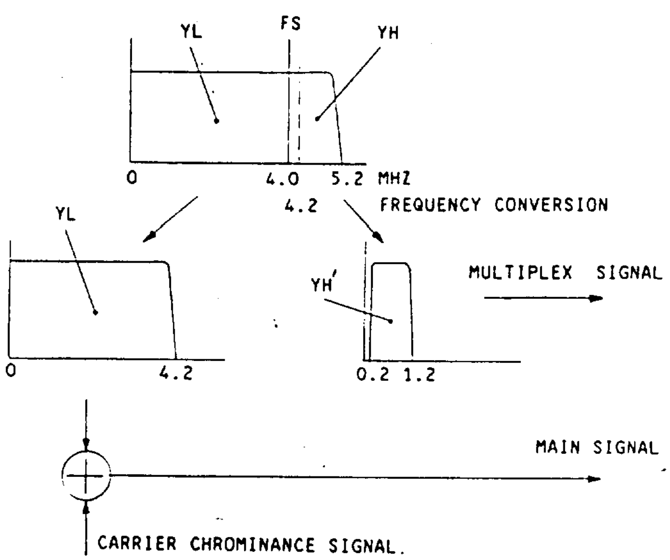


Fig. 8. Frequency Spectrum of the Multiplex Signal

C. Inverse Nyquist Filter

The performance of a conventional NTSC receiver was evaluated by the RF band QUME signal, and heavily influenced by inverse nyquist filter. It is important to balance the frequency characteristic of the inverse nyquist filter and that of the nyquist filter in the receiver. The frequency characteristics of a current nyquist filter and a sample of inverse nyquist filter are shown in

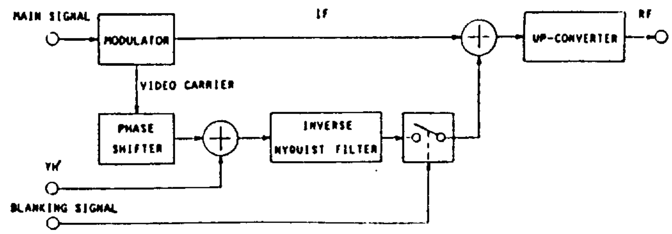


Fig. 9. Block Diagram of the Modulator

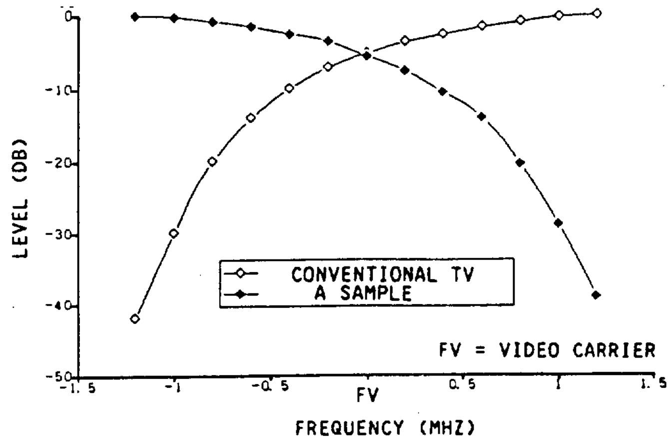


Fig. 10. Frequency Response of the Nyquist Filter and the Inverse Nyquist Filter

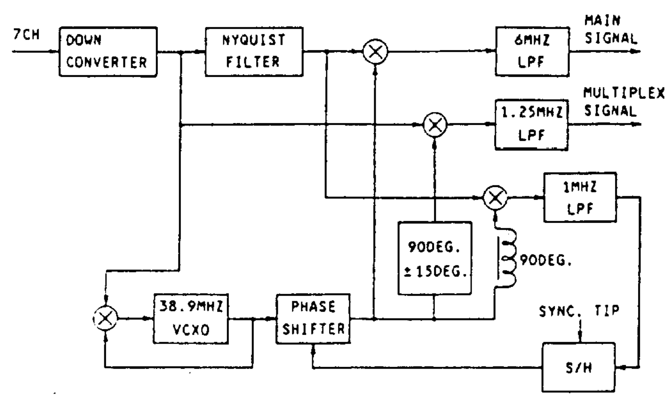


Fig. 11. Block Diagram of the Demodulator

Fig. 10. This sample shows almost symmetrical characteristics and there is little problem with interference from the multiplexed signal to the conventional receiver.

D. Demodulator and Decoder

Fig.11 shows a block diagram of the demodulator. The incoming RF signal is converted to IF by the down-converter. The main NTSC signal is detected by a PLL synchronous detector after passing through a nyquist filter, and the multiplexed $Y_H{}'$ is detected by a 90 degree shifted video carrier and passes a 1.25MHz LPF.

A block diagram of the decoder is shown in Fig.12. Both of the main NTSC signal and the multiplex signal are converted to digital form and the latter is fed to a converter. Y_H' is frequency shifted to Y_H, added to the main signal, and generates a wide band NTSC composite signal. A motion adaptive Y/C separator, a scanning converter, and a chrominance detector are employed to improve picture quality. Analog Y, I and Q signals are fed to the display after D/A conversion.

E Frequency of subcarrier

To prevent buzz and maintain phase of regenerated video carrier in a conventional receiver, subcarrier frequency f_s for shifting the high frequency component of luminance signal must be chosen so that the shifted signal Y_H' does not include DC component. In this experiment, f_s uses 4.0MHz and such interference was not present.

Furthermore, to eliminate crosstalk from the main NTSC signal to the multiplex signal at the demodulator, the subcarrier f_s is line and field offset. The multiplex signal was successfully detected by the offset subcarrier, and the crosstalk from the multiplex signal to the main NTSC signal is too small to degrade the main picture.

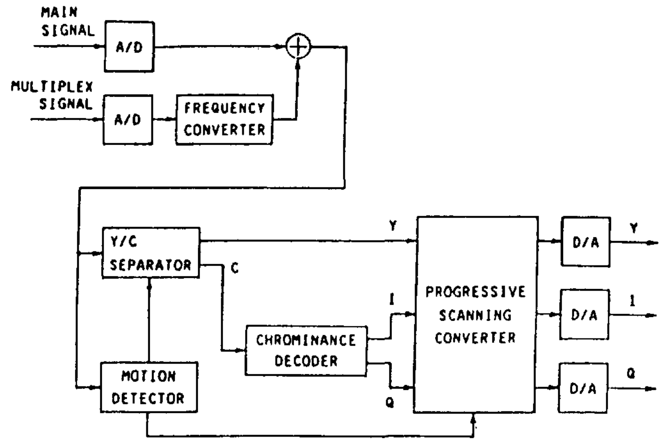
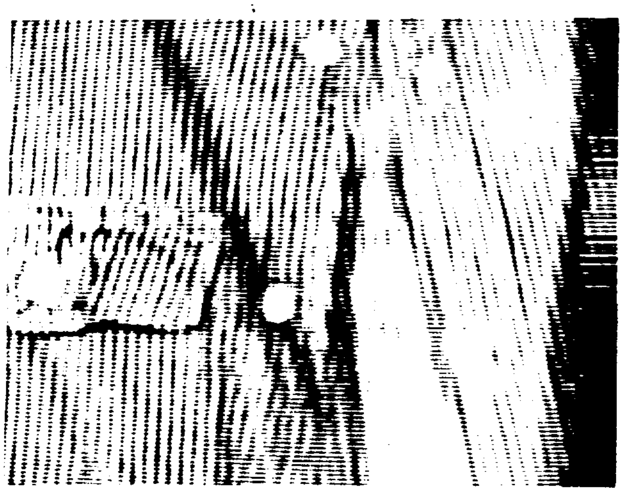


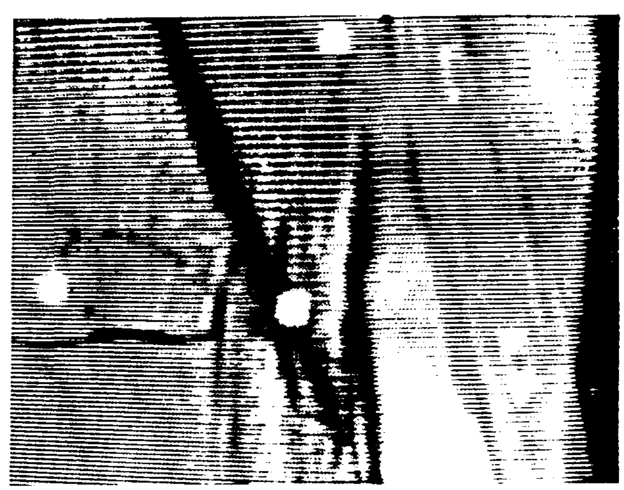
Fig. 12. Block Diagram of the Decoder

(a) QUME (Luminance : 5.2MHz)

(b) NTSC



(c) QUME (enlargement)



(d) NTSC (enlargement)

Fig. 13. Photographes of QUME and NTSC pictures

F. Results

Fig.13 (a) shows an example of picture obtained by the experimental QUME system, and (b) shows a picture by a NTSC receiver. Y_H (4.2 - 5.2MHz) was successfully transmitted and regenerated by a QUME receiver. This experimental system shows that the high frequency component of luminance signal of motion picture as well as still picture can be transmitted.

A small degradation of the main NTSC signal by multiplexing was detected but far less than an allowable level on the receiver with the quasi synchronous or envelope video detector. No degradations were found on the receiver with the PLL synchronous detector.

Fig.14 shows crosstalk from the multiplex signal to the main NTSC signal. In this figure, it reveals that the crosstalks on the receivers with the envelope detector and with the PLL synchronous detector were about - 20 dB and - 35 to - 45 dB, respectively. The former level can be accepted if the multiplex signal is high frequency component as seen in the experiment, and the latter level leads to the possibility of transmitting various other multiplex signals.

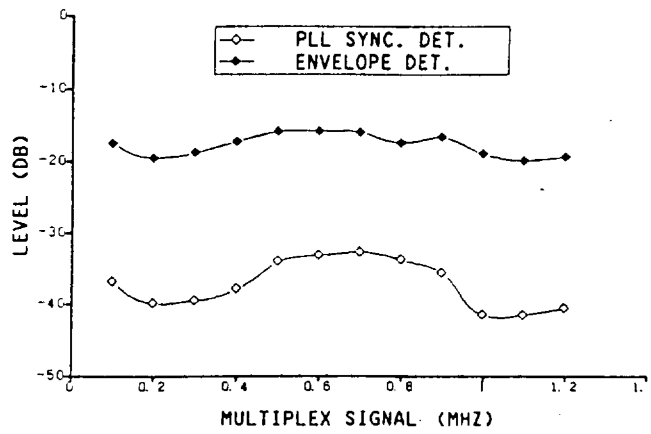


Fig. 14. Crosstalk from the Multiplexed Signal to the Main NTSC Signal

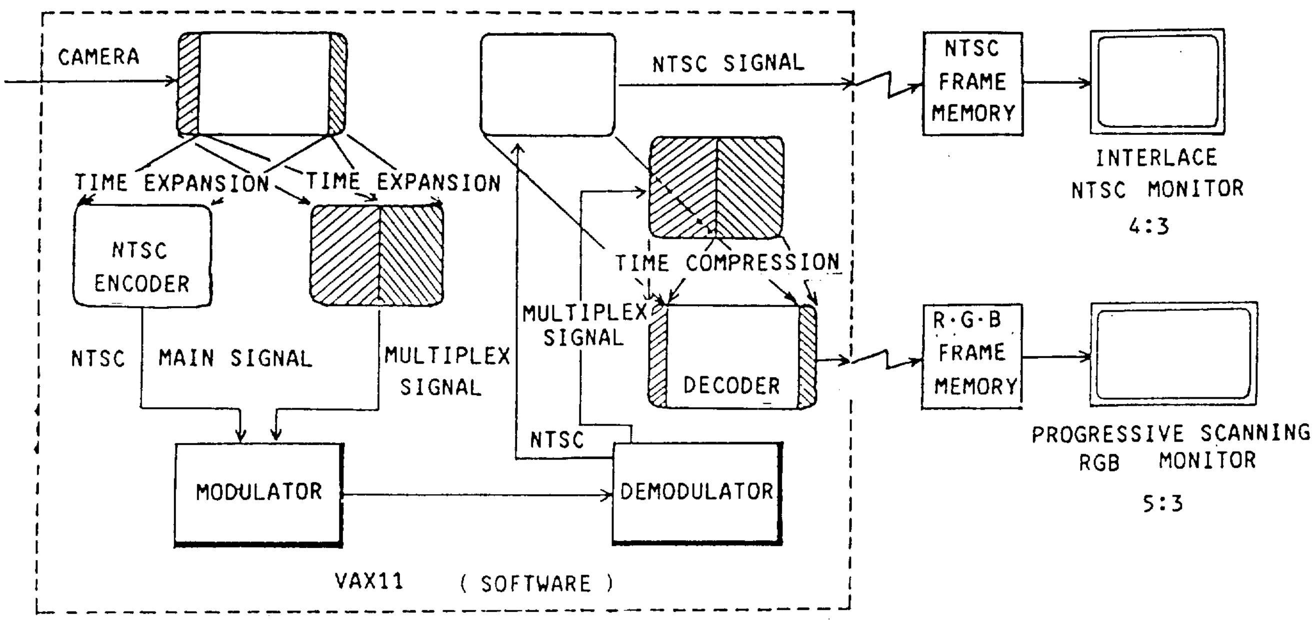


Fig. 15. Simulation of QUME Wide Television

IV. TRANSMISSION OF WIDE ASPECT RATIO IMAGE

Using an additional channel of quadrature modulation, it is possible to increase the aspect ratio from the current 4:3 to at least 5:3. To check the feasibility of wide television, computer simulation to transmit edge portions of wide aspect ratio image was made.

A. Simulation of Wide Television

Fig.15 shows hardware and program flow of the computer simulation. The original wide aspect ratio RGB images are previously taken by a progressive scanning camera, and 2 frame memories and monitors are connected to a host computer, VAX11/785. The first step is to separate center image and edge images of the 5:3 image, and time-expand them. The center portion is expanded by 1.25 to the conventional 4:3 image and encoded into NTSC format, and transmitted as the main signal. The edge portions are expanded by 5 to 1 MHz bandwidth signal, that is transmitted as the multiplex signal.

There are some methods of encoding luminance and chrominace signals of the edge portions, such as time compression integration and TAT [8]. In this simulation, a subcarrier $f_{sc}/5$ (f_{sc} = 3.58 MHz) is used to multiplex chrominance signal just as the same fashion in NTSC system. Fig.16 (a) shows the frequency spectrum of the NTSC signal and (b) and (c) show the multiplex signal with modulated chrominance signal of the edge portions before and after passing an inverse nyquist filter, respectively, and (d) shows the generated QUME signal obtained by combining (a) and (c).

QUME modulation and demodulation is implemented in software. The center portion is demodulated and decoded in the fashion of the normal NTSC, and displayed on a NTSC monitor. The edge portions are demodulated by a PLL synchronous video detector and time-compressed by 5, and combined with the time-compressed center portion. The combined image is displayed on a 5:3 aspect ratio progressive scanning monitor.

B. Results

Fig.17 shows images on the 2 monitors in this simulation: (a) is a composed wide aspect ratio image of an RGB monitor, that is a QUME wide television. In this picture stiches of two image portions are almost invisible, although no special processing [5] is introduced. Fig. 17 (b) is an image of a NTSC monitor that is equivalent to the conventional receiver with the PLL synchronous detector. There is no degradation in this picture caused by multiplexing edge images. But some interference is detected in the case of the quasi synchronous and envelope detector, especially on the white portion of images.

By displaying a 5:3 aspect ratio image, reality and impression are increased[9] and its preference has been pointed by almost all people who have watched the images generated by this simulation.

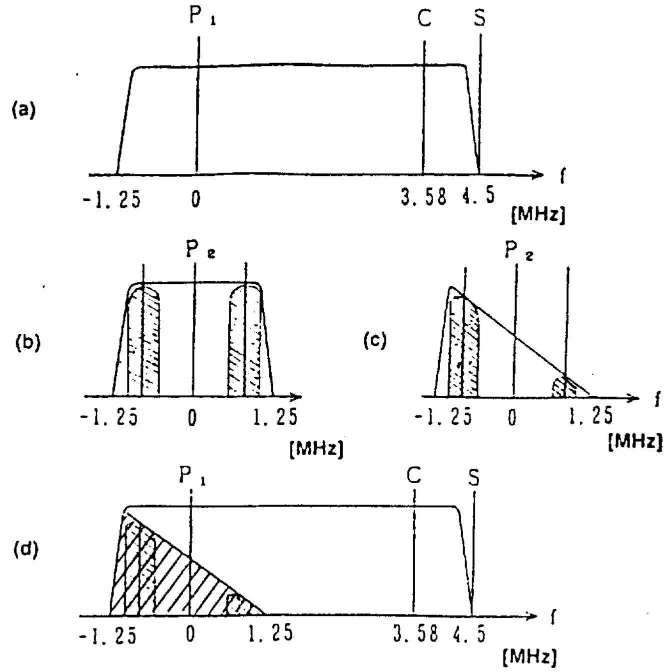


Fig. 16. Spectrum of Wide Television
(a) NTSC (b) Multiplex Signal before Inverse Nyquist Filter
(c) Multiplex Signal after Inverse Nyquist Filter
(d) QUME Wide Signal

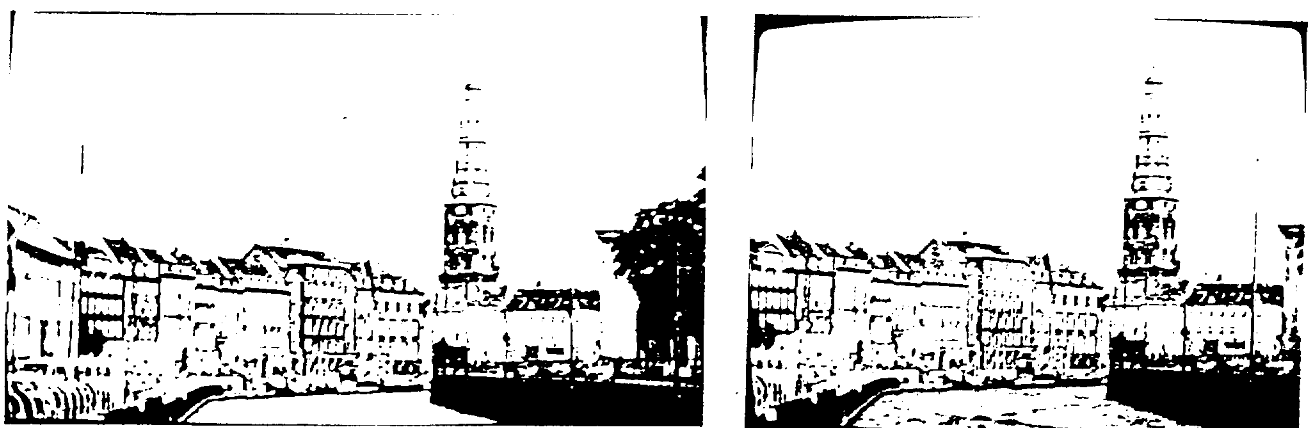


Fig. 17. Photographs of 5:3 and 4:3 pictures
(a) 5:3 RGB Monitor (b) 4:3 NTSC Monitor

V. CONCLUSION

In this paper, QUadrature Modulating Extended definition television -QUME- system is introduced and the first experimental system which transmits the high frequency component of luminance signal has been developed. The experiments reveals the feasibility of the QUME system, that the multiplexed signal hardly interferes with the NTSC main signal and thus the compatibility is maintained, and the transmitted multiplexed signal is successfully demodulated and wide band luminance signal is regenerated on the display in the moving part as well as in still images.

The computer simulation reveals that a wide aspect ratio image can be transmitted by using the QUME system. NTSC terrestrial broadcasting can move to wide television system -improving aspect ratio from 4:3 to at least 5:3 -, keeping full compatibility with the conventional receivers. The QUME system is so flexible as to transmit various multiplex signals, and applicable to PAL and SECAM as well.

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A Ghost Cancelling Using Pseudo Random Signal Train

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I. INTRODUCTION

The leading edge of a vertical synchronous signal has been used as a reference signal for a ghost canceller in a television receiver. However, the leading edge is not strictly standardized nor steep enough, and does not keep perfect correlation with video signal. Accordingly, a reference signal that is dedicated to the cancellation of ghosts is required. Therefore, we proposed an original system to use pseudo random signal train as the Ghost Cancelling Reference signal.

II. PSEUDO RANDOM SIGNAL TRAIN

The pseudo random signal train is made by filtering a pseudo random binary level sequence with a filter satisfying the first Nyquist criteria. A waveform of this signal train used as the GCR signal is shown in Fig. 1. The frequency characteristics of the pseudo random signal train , which is band-limited by the filter, are shown in Fig. 2.

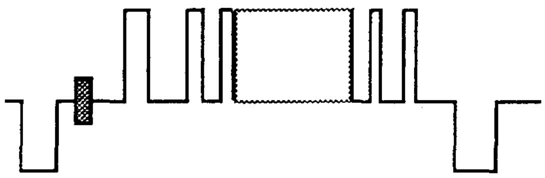

Fig. 1. Pseudo random signal train

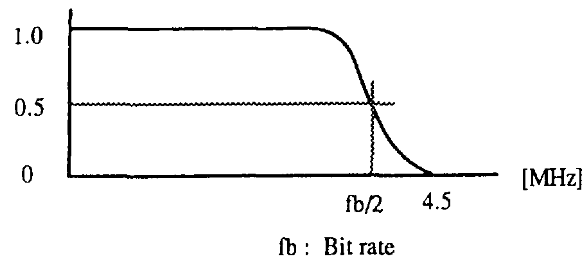

Fig. 2. Frequency characteristics of pseudo random signal train

The following advantages are obtained when this signal train is used.
(1) Less affected by noise than other GCR signals
(2) Data transmission is possible by bearing an information on the pseudo random sequence.
(3) No reference generator is required in a television receiver.

III. CONFIGURATION OF GHOST CANCELLER

A block diagram of a ghost canceller using the pseudo random signal train is shown in Fig. 3. The output of the transversal filter is sampled and converted into binary level sequence with a decision circuit. The error between this binary level sequence and sampled output signal of the transversal filter is detected and minimized by repeating the correction for the tap coefficients of the transversal filter.

Although the reference signal must be generated in a television receiver if pulse signal or bar signal is used as GCR, no reference signal generator is required for the pseudo random signal train.

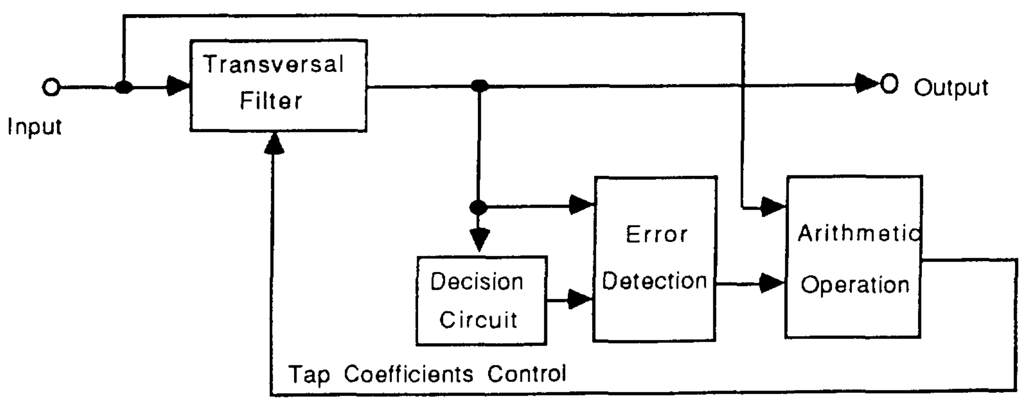

Fig. 3. Block diagram of the ghost canceller

ADAPTIVE EQUALIZER FOR TELETEXT RECEIVER

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Abstract

We have developed a new fully-digital adaptive equalizer for teletext receivers which counteracts waveform distortion using teletext signals as reference signals and compensates equalized waveforms. This equalizer reduces the bit error rate vs. video signal S/N to 1/100 that without the equalizer.

1. Introduction

Teletext quality is greatly affected by nearby ghosts and waveform distortions due to frequency characteristics of the teletext receiver. To improve the quality of received teletext, many types of analog equalizers using CCD devices have been developed. Almost all use the leading edge of a vertical synchronizing signal as the reference signal. When such analog devices are used, the quality of teletexts received is greatly affected by ambient conditions (temperature, humidity etc.); quality is also degraded by the instability of the vertical synchronizing signal.

We have developed a new, fully-digital adaptive equalizer for greater improvement of teletext quality (bit error rate vs. video signal S/N 1/100 that without equalizer).

We have also developed low-power-dissipation C-MOS LSI (2 μm) for teletext receivers.

2. System Description

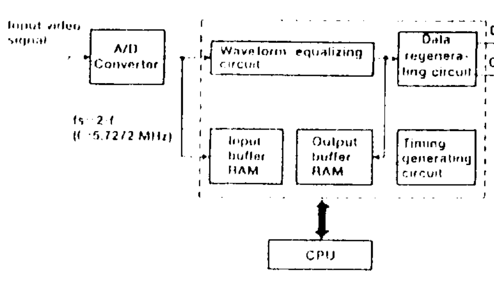

Fig. 1 Schematic Diagram of Adaptive Equalizer

Fig. 1 is a schema of the adaptive equalizer. As shown in this figure, it consists mainly of an A/D converter, a waveform equalizing circuit, input/output buffer RAM, a data regenerating circuit, and a timing generating circuit. These are controlled by an external CPU. The A/D converter quantizes input video signals at a sampling frequency of 11.4544 MHz (twice the transmission frequency of teletext signals, 5.7272 Mb.p.s.). The number of quantizing bits is set at 5. These transmission and sampling phases are asynchronous. The quantized video signal is output to the waveform equalizing circuit. The teletext signals superposed during the vertical blanking interval, are extracted from waveform equalizing circuit input and output at the DMA (Direct Memory Access) timing from the timing generating circuit.

The external CPU corrects the transversal filter tap coefficients according to an operation based on the MSE (Mean Square Error) algorithm. The data regenerating circuit regenerates data and clock signal is equivalent to those obtained by quantizing post-waveform equalization data at optimum sampling timing; then serial data of 5.7272 Mb.p.s. and clock signals of 5.7272MHz are output.

3. Waveform Equalizing Circuit

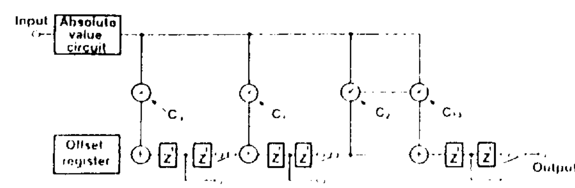

Fig. 2 Block Diagram of Transversal Filter

The waveform equalizing circuit consists of a 14-tap transversal filter; the internal operation is executed by 6 bits. In order to obtain optimum tap coefficients, an MSE algorithm based on our original correlational operation has been developed. Fig. 2 shows the block diagram of the transversal filter. It is of the pipeline-configuration, feed-forward control, input-addition type, and the tap spacing of 1 clock delay (87.3 nsec) and 2 clock delays (174.6 nsec) can be controlled by the CPU. An offset register is placed on the first stage undertaking both DC offset to DC level shift and the setting of the slice level. The tap coefficients are corrected in accordance with the result of the correlational operation (1) below; a sequence of error signals, which is obtained by calculating the difference between the preset reference level and the post-waveform equalization data and the pre-waveform equalization data are applied to the formula (1). The formula (1) here indicates a correction of the i^{th} of N taps. (N is the total number of taps.)

The feedback coefficient α is controlled according to residual errors to improve stability and convergence.

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In the initial stages of the operation, a large figure is applied to α, in order to improve convergence. After the installment, a small figure is applied to α to ensure stability.

To avoid divergence, the sum of all coefficients is calculated to detect the state of the coefficients every time tap coefficients are corrected.

$$C_i^{(n+1)} = C_i^{(n)} - \alpha \sum_{k=1}^{N} X_{k-i} E_k^{(n)} \quad \ldots (1)$$

$C_i^{(n)}$: tap coefficients (after n times correction)

X_i : input signals

$E_i^{(n)}$: error signals (after n times correction)

α : feedback coefficient

4. Data Regenerating Circuit

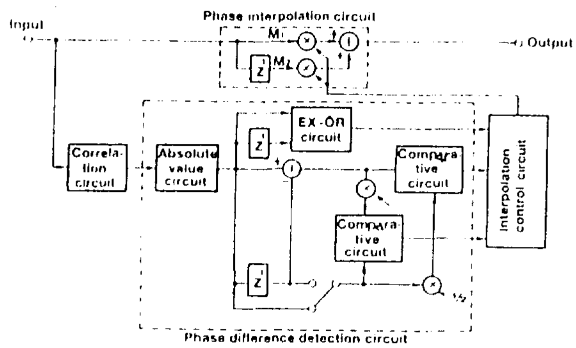


Fig. 3 Block Diagram of Data Regenerating Circuit

A phase interpolation circuit composed of simple hardware has been developed for the data regenerating circuit to match the sampling phase of the A/D converter with that of the clock frequency. Fig. 3 is the block diagram of the data regenerating circuit.

This circuit is mainly composed of a correlational circuit, phase difference detection circuit, interpolation control circuit, and a phase interpolation circuit.

The correlation circuit extracts the CR (clock-run-in) signal and integrates it; the integration is fed to the phase difference defection circuit according to the timing generating circuit. The phase difference detection circuit detects the phase difference between optimum sampling timing and quantization timing, using amplitude and polarity of two continuous sampling data of the CR signal integral calculus and the phase error of the detection is within 11.3°. According to the detected phase difference, the interpolation control circuit controls the phase interpolation circuit, phase-shifts, which is equal to the quantization at optimum sampling timing, and regenerates data and the clock signal.

In Fig. 4, a, b, a', and b' are four samples obtained during one cycle (T = 1/5.7272 μsec) of the CR signal; each sample has a phase difference of 90°. C and C' are transmission clock timings. φ indicates the phase

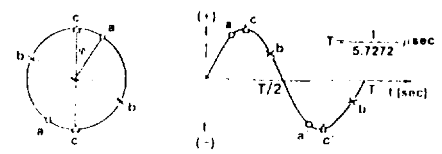


Fig. 4 One-Cycle Sampling Data of CR Signal

difference between transmission clock timing and quantization timing; the difference is 45° at worst. When sampling frequency is 5.7272 MHz, equal to the transmission rate, on the other hand, two samples can be obtained during one CR cycle, these samples have a phase difference of 180°. When the phase difference between transmission clock timing and quantization timing is 90°, data cannot be regenerated, the output timing of the integrated CR signal, four combinations of these samples make up the input of the phase difference detection circuit: (a, b), (b, a'), (a', b'), and (b', a). Of these combination, we will explain, a particular situation in which the relation between the amplitude of samples a and b, |a| and |b|, is given as |a| > |b|.

The formulas (2) ~ (4) below indicate conditions of the quantitative relation between |a| and |b| and their relation with detected phase difference φ.

$|a|\;\;|b| > 4\cdot|b|$: $0° \leq \varphi < 11.3°$ . . . (2)
$1/2\cdot|b| \leq |a|\;\;|b| \leq 4\cdot|b|$: $11.3° \leq \varphi \leq 33.7°$ . . . (3)
$|a|\;\;|b| < 1/2\cdot|b|$: $33.7° < \varphi \leq 45°$ . . . . (4)

According to these formulas, the phase interpolation control circuit sets the ratio of coefficients M_1 and M_2 of the multiplier in the phase interpolation circuit at 1:0, 1:1/2, and 1:1. Phase is shifted by putting a and b in these ratios. In other words, the phase interpolation circuit is a 2-tap transversal filter with tap coefficients M_1 and M_2.

Fig. 5 is a schema of phase interpolation based on phase shifting of three different ratios.

P and P' indicate sampling points obtained by phase interpolation; each indicates, respectively, that the phase difference between transmission clock timing and quantization timing has been reduced from φ to φ_1 in (ii), and from φ to φ_2 in (iii).

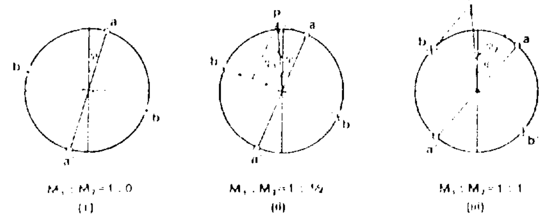
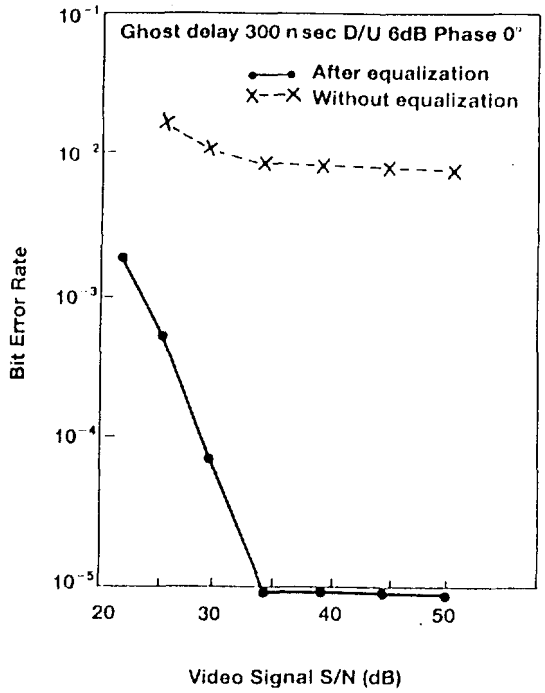


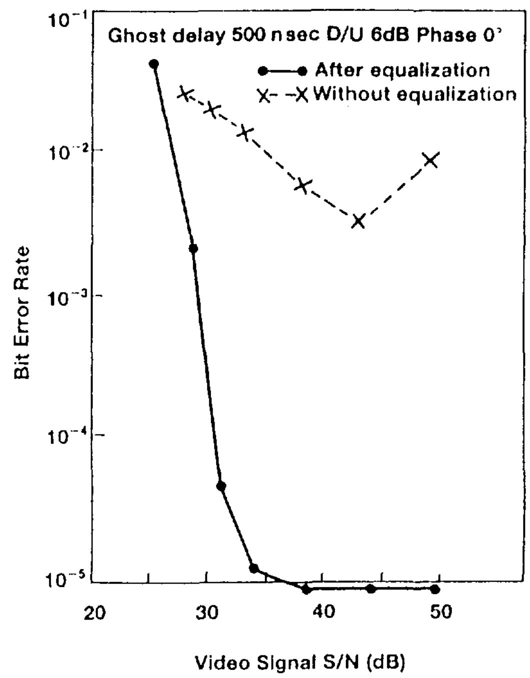
Fig. 5 Illustration of Phase Interpolation

5. Waveform Equalization Efficiency

Fig. 6 shows the bit error rate vs. input video signal S/N on condition that the ghost is single and its delay is, in (i), 300 nsec, phase 0°, and in (ii) 500 nsec, phase 0°. By waveform equalization, the bit error rate is reduced to 1/100 of what it would be without the equalizer.



(i)



(ii)

Fig. 6 Bit Error Rate vs. Video Signal S/N

6. LSI Features

The LSI has been designed emphasizing high-speed operation, minimization of chip size, and reduction of power dissipation. The LSI features are as follows:

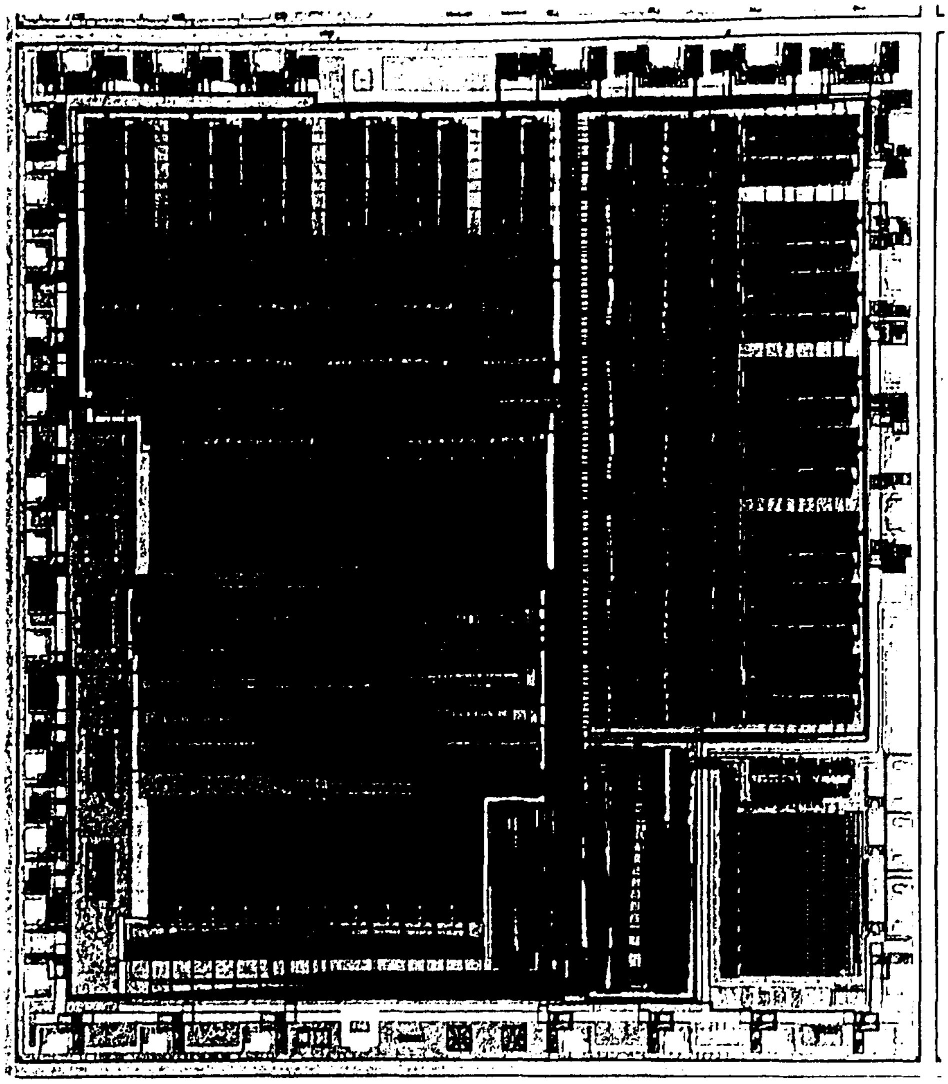
1) The number of elements in the multiplier can be reduced by dividing the basic filter block of the transversal filter into 5-bit and 6-bit configurations and by multiplying tap coefficients and transversal filter input with absolute values respectively.
2) High-speed operation can be realized by implementing 2-phase clock writing in DMA mode, in which transversal filter input and output are directly stored in RAM.
3) 40% reduction of power dissipation is possible by halting the A/D converter while teletext-signals are not accumulating.
4) Wiring field, resistance, and capacity can be decreased by arranging each block along the signal flow.

LSI Specification

Process	CMOS 2μm
Chip size	5.73mm×6.52mm
Elements	42,000 transistors
Package	40 PIN DIL
Power dissipation	300mW (typ.)
Basic clock frequency	11.4544 MHz
Input buffer RAM capacity	5×192 word
Output buffer RAM capacity	6×192 word

7. Conclusion

This newly developed adaptive equalizer makes it possible to provide teletext service to a wider range of areas where previously teletext reception was impossible due to ghosts, group delay distortions which occur at the transmission line, or waveform distortions caused by frequency characteristics of the receiver. Moreover, with the use of an algorithm which uses teletext signals superposed on television signals as the reference signal, the application of the adaptive equalizer to waveform equalization in data transmission, whose transmission frequency is almost equal to that of teletext, can be also considered. On the other hand, for the efficiency of the adaptive equalizer, the hardware structure, convergence, and stability are important factors. Therefore, for the purpose of improvement of convergence, and preventing over-equalization and divergence, the tap coefficient control algorithm is very important. In this matter, various studies are being made; this new adaptive equalizer employs the MSE algorithm and ensures stability and a convergence time of 10 seconds or less. From now on, we will develop a ghost canceller using this technique.



Photograph of the LSI

Acknowledgments

In closing, the authors would like to express their deepest gratitude to Mr. Nakajima, Director of the Wireless Research Laboratory of Matsushita Electric Industrial Co., Ltd. for giving us the opportunity to do this research, and to those of the Television Division and Video Equipment Division of Matsushita Co., Ltd. and Matsushita Electronics Corp. for their generous support.

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